# The Response of a Tropical Fish to Direct Current and Its Application to the Problems of Electrofishing in Sea Water[1]

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METHODS OF ELECTROFISHING have been developed successfully for use in fresh-water ponds and streams, but this equipment is not effective in sea water because the high conductivity of salt water greatly changes the power requirements (Smolian, 1944). If this obstacle can be overcome, it is reasonable to assume that electrofishing can be conducted in the sea with a success which would be at least equivalent to that experienced in fresh water.

Electrofishing in fresh water is now widely practiced in Germany, the United States, and Canada, where it is used mainly as a new tool to supplement the facilities for study of fish populations. The progress made in Germany has been described by Smolian (1944) in a comprehensive report which includes a description of the equipment and techniques used in that country. In the United States, the first efforts concerned with the reaction of fish to electrical stimulation centered around the development of electric fish screens and began as early as 1917 (Holmes, 1948). However, a method of actually collecting fish in fresh-water streams was first developed in 1939 (Haskell, 1940).

Equipment used for electrofishing in fresh water has consisted mainly of small, portable, gas-driven generators which produced alternating current. However, Smolian (1944) reported that the greatest effect seemed to be realized from using direct current interrupted at frequent intervals. Large fish were affected more strongly than small ones. There was also considerable variation in the sensitivity of various species to electrical stimulation.

In reports from both the United States and other countries it has been emphasized that paralyzing, narcotizing, and attracting the fish can be accomplished only in the immediate vicinity of the electrodes. Outside this area the current merely irritates the fish and frightens them away.

While some reports have been made concerning the injurious or fatal effects of electrofishing (Hauck, 1949), it appears that fish can be collected by using current strengths below those which will injure or kill.

German scientists have been investigating the possibility of adapting electrofishing techniques for use in salt-water fisheries. At the present time it has been reported (Anon., 1951) that they are in the process of installing electrical fishing gear on a boat of the type used in the trawl fishery. Only general newspaper-type reports have been published concerning this work. The basic research was financed personally by the scientists concerned so it is assumed that no detailed information will be forthcoming until their work has reached a patentable stage.

These reports indicate that their claims of success in the development of electrofishing equipment suitable for use in sea water are based on the more efficient utilization of electricity rather than in merely increasing the amount. Special mention is made of pulse shape, pulse rate, and electrode arrangement.

The response of living organisms to electrical stimulation was investigated as early as

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1885 by Hermann. He reported that tadpoles, when in a field of direct current of proper strength, would react by orienting themselves with their heads toward the positive pole. Since that time, experiments have been conducted with numerous animals, including crabs, fish, and frogs. Practically all types of animals tested show an orientation to the current. Many protozoans, however, orient and migrate toward the negative pole rather than the positive (Heilbrunn, 1948: 597).

Considerable research has been done in an attempt to explain the physiological reasons for this reaction (Breuer, 1905; Scheminsky, 1924; Van Harreveld, 1937). However, these reports indicate that it is still imperfectly understood. As nearly as can be determined, no satisfactory explanation of this phenomenon has been given.

I wish to express my appreciation for the advice and assistance given by Dr. A. L. Tester in the preparation of this manuscript and over-all supervision of the investigation.

## METHODS

The period covered by the investigation here reported extended from May, 1950, to March, 1951. Work was begun at the Hawaii Marine Laboratory on Coconut Island and continued there throughout the summer months. At the beginning of the academic year, all the equipment was transferred to the Waikiki branch of the Hawaii Marine Laboratory. This branch, operated in conjunction with the Honolulu Aquarium, offered certain advantages over the previous site, principally its proximity to the University of Hawaii. All the detailed experimental work reported in the following pages took place at the latter site.

### *Power Supply*

The generating equipment was selected to give the widest possible range in current and voltage while still being portable and of standard design.

As direct current was more likely to produce the reaction desired, an Onan two-cylinder, gas-driven, air-cooled, portable-type, direct-current, motor-generator set was purchased. It was rated at 5,000 watts (21.8 amperes at 230 volts). Special equipment included a voltmeter, ammeter, rheostat, and circuit breaker.

### *Electrodes*

The high conductivity of the sea water caused serious overloading of the generator. Plans for overcoming this difficulty centered around the use of rheostats and suitable electrodes. However, the rheostat installed to control the voltage and current was ineffective and various other resistors devised to control the current flow proved unsatisfactory. A special electrode was finally developed for use during the experiments. This consisted of a carbon rod 6 inches long and ¼ inch in diameter inserted into a plastic tube (Fig. 1). The size and number of holes in this tube governed the flow of current. In effect the column of sea water inside the tube became the electrode, as the area of this column in

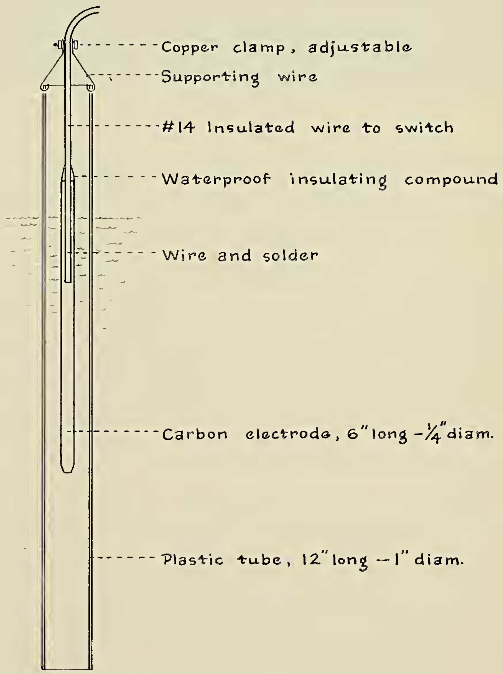


FIG. 1. Electrode design.

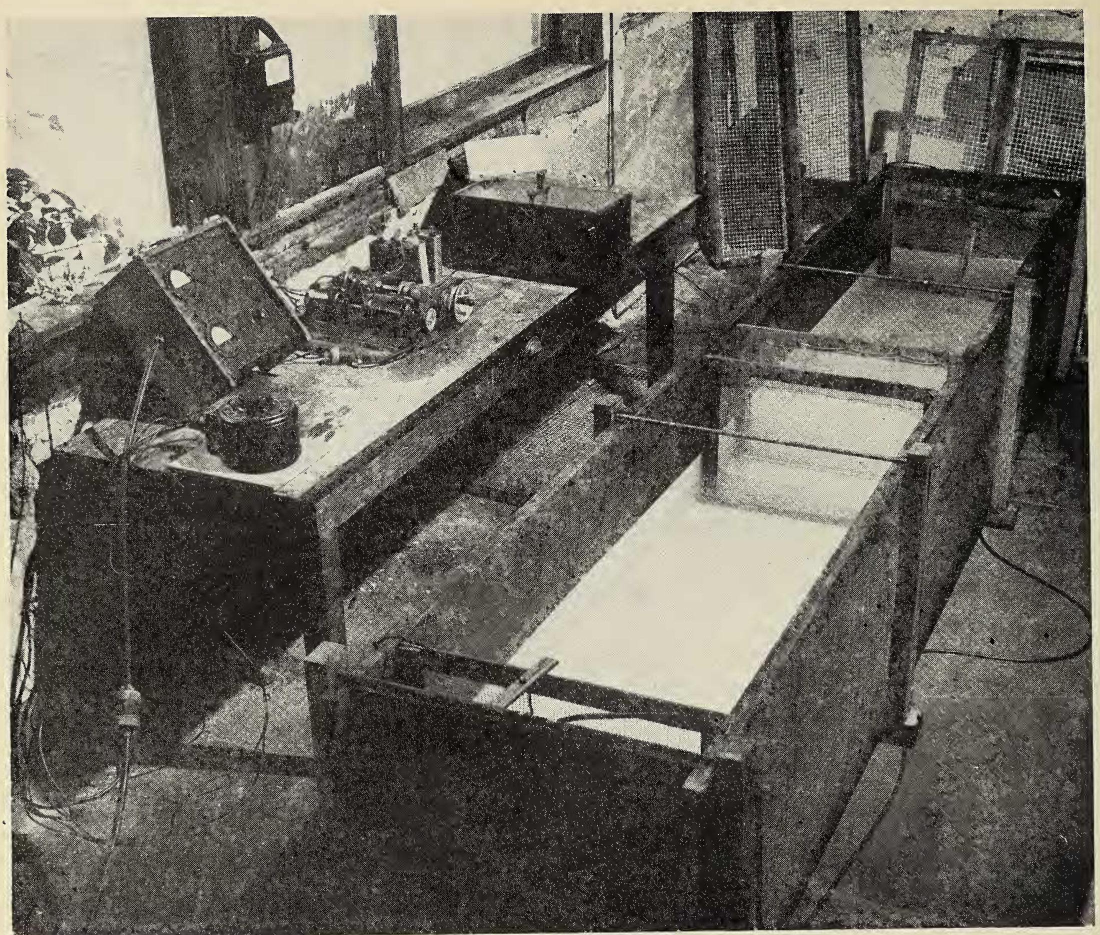

FIG. 2. Experimental tank and current-interrupting equipment.

contact with the main body of water in the tank determined how much current would flow. As the entire electrode was covered by water, gases formed on its surface evenly, and their escape did not affect the current flow. With this arrangement, it was possible to lower the enclosed electrode to any depth without changing the current flow, and a more symmetrical field could be created at each end of the tank.

Carbon was chosen as the most suitable electrode material because it is a fair conductor, inexpensive, and does not erode rapidly with electrolysis as do most metals.

To remove the products of electrolysis as they were formed and to prevent contamination of the water (chiefly by chlorine) in the tank, the water within each electrode was siphoned off continuously be means of a rubber tube. The loss of water from the tank was compensated for by a steady addition of new water.

*Tank*

A tank measuring 2 × 2 × 12 feet was constructed from redwood. The inner surface was thoroughly impregnated with heated paraffin to prevent leaching and to aid in waterproofing. Net barriers were placed about 1 inch in front of each electrode to prevent the fish from injuring themselves by contact with the electrode. Two other net barriers were arranged across the center of the tank to form a small area in which the fish could be held when not actually under observation (Fig. 2).

*Current Interrupter*

After overloading had been controlled, preliminary experiments showed that the full load of the generator, approximately 20 amperes and 230 volts, would not attract and hold fish about 4 inches long in a concrete tank 10 feet square filled with water to a depth of 2 feet. When the fish swam near the electrodes, they were effectively held, but they would remain at the greatest distance possible from the electrodes or in the corners of the tank near the bottom.

Thus it became obvious that, if a steadily flowing current was to be used, a much greater source of power would be needed. A similar observation was made by Peglow (1949). To attract the fish to the positive pole a much more efficient use of the available power would be necessary. The best possibility of accomplishing this, according to the general reports of previous investigators, would be through the use of interrupted current (Smolian, 1944; Anon., 1950).

Various mechanical devices were constructed, mainly from war surplus material, for the interruption of direct current. First attempts centered around the use of relays, but for various reasons these did not prove practicable. It was difficult to determine the exact duration of the power-on period compared with the power-off period. When operating at higher interruption frequencies and with the higher power values, the arc became very difficult to control, even with condensers. Observation of the wave form on an oscilloscope showed that, if the power-off period was short, the arc often lasted over the entire period. The relay points frequently became heated and failed to separate. It was also difficult to determine the exact number of interruptions per second.

A revolving disc-type interrupter was finally decided upon. Although not satisfactory

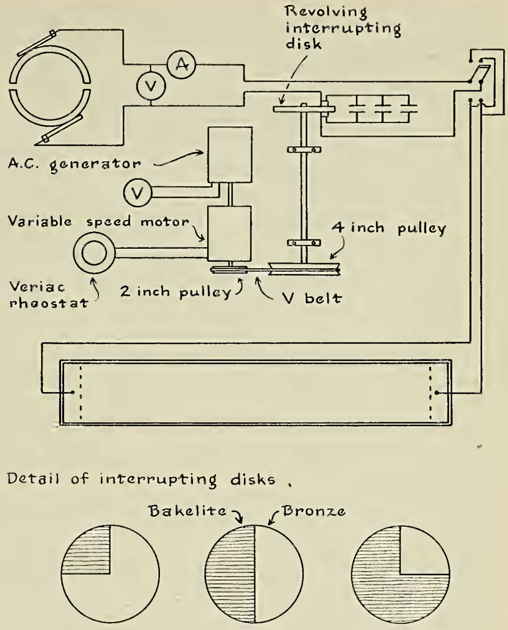


FIG. 3. Diagram of current-interrupting equipment used in experiments.

in every respect, it at least overcame most of the objectionable features of previous equipment (Fig. 3).

Carbon brushes bearing on either side of the disc provided a constant connection when the bronze portion of the disc was between them. When the disc revolved, the connection was definitely broken when the Bakelite portion was between the brushes. Some arc was unavoidable, but an attempt was made to minimize this by three condensers (10 mfd., 600 volts, d.c.) arranged in parallel. A variable speed motor controlled by a "veriac" was used to turn the disc.

A small generator was connected directly to the shaft of the motor. The voltage produced by the generator was recorded on a voltmeter. The relationship between voltage and speed was determined so that, by reading the voltage on the voltmeter, the speed of the generator and, therefore, of the motor could be calculated.

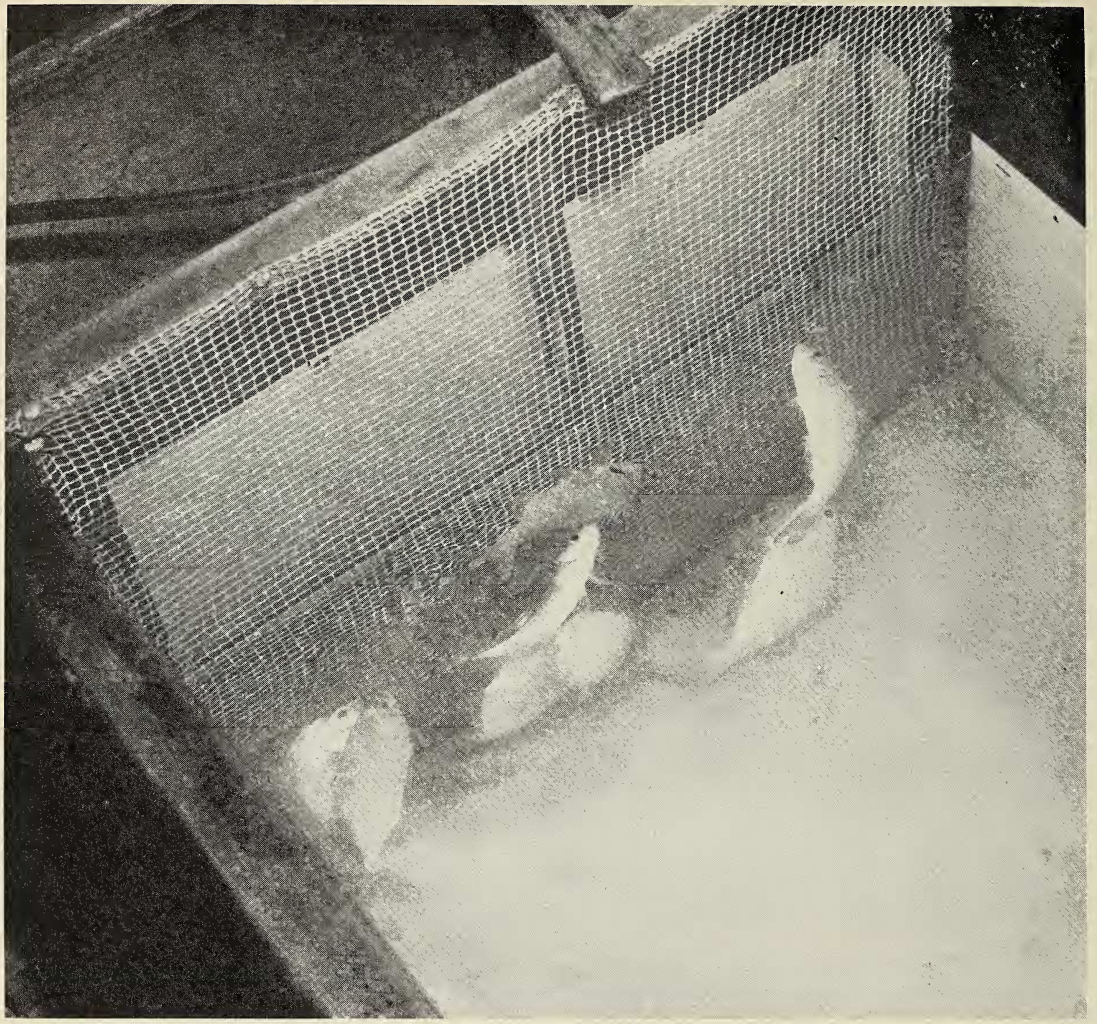

FIG. 4. The experimental fish, *Kuhlia sandvicensis* (Steindachner), attracted to the positive pole and immobilized there by the use of interrupted direct current.

*Fish*

The fish chosen for the experiments was *Kuhlia sandvicensis* (Steindachner) (Fig. 4), locally called aholehole. This fish is bright silvery when viewed from the side but appears dark blue when seen from above. It spawns along the shoreline and is quite plentiful in the brackish water near the mouths of streams and canals where it grows to a size of approximately 25 cm.

Aholehole were recommended for the experiments because of their hardiness and ability to survive considerable handling. This turned out to be a fortunate choice, for enough of the fish were caught in traps in Ala Wai Canal to supply all experimental needs. The fish were held and fed in tanks of the Honolulu Aquarium when not actually being used for experimentation. They proved to be admirably suited for the purpose intended. After a rather high initial mortality due to injury by trapping, practically none died, either from handling or from the effects of electrical shocks.

Experimenters have been unanimous in their reports that larger fish are affected more strongly than smaller fish, so an attempt was made to control this factor by selecting fish of approximately the same size for the experiments. The range in size was from 9.5 cm. to 15.0 cm., the mean size was 11.8 cm., and the standard deviation was 1.04 cm.

*Procedure*

The collection of quantitative data on the reaction of fish to electrical stimuli was considered highly desirable, and an experimental plan was formulated with this in mind. The main object of the experimental work was to cause the fish to move, involuntarily, to the positive pole, where it would be held, either by a strong attractive force or by passing into a condition of electronarcosis. To eliminate, as far as possible, subjective observations and to measure this effect under different electrical conditions, the experimental design discussed in the following paragraphs was used.

The tank was considered to consist of two equal sections, positive and negative. The fish were held in the center of the tank between two net barriers. When the power was turned on, the barriers were removed. The power remained on for 60 seconds. During this period, the time the fish spent in the positive section was recorded. Under optimum electrical influence, the fish, when released from the center area, would move directly to the positive pole and become immobilized, thus spending the full period of 60 seconds in the positive section. When no influence was in effect, the fish (over an average) would be expected to spend 30 seconds in the negative section and 30 seconds in the positive section.

A two-pole, double-throw switch was placed in the circuit so the polarity could be reversed. This obviated the possibility that some influence other than electrical stimulation might cause the fish to seek one end of the tank more consistently. Each fish was given two timed trials, the polarity being reversed in the second trial. To determine whether the movements of the fish in the tank were random, preliminary trials were made with the power off. Ten tests were made using individual fish. They spent an average of 31.8 seconds in the positive section and 28.2 seconds in the negative section. These average times did not deviate significantly from the expected times of 30 seconds in each end of the tank, so it was concluded that movement throughout the tank was random when the current was off. Timed trials were also made with several fish in the tank at the same time. However, individual variation made accurate timing of each fish difficult, so it was decided that fish would be used individually rather than in groups.

During the experiments, the voltage remained relatively constant (220–230 volts). The depth of water in the tank was 12 inches, and the distance between electrodes was 11 feet. These factors were constant for all tests.

One group of experiments was conducted with continuously flowing (uninterrupted) current. In it were included a series of experiments at amperages of 1 to 14, inclusive. The current in amperes may be converted to density in milliamperes per square inch by multiplying the amperage by the factor 3.62. Thus, 14 amperes is equivalent to a current density of 51 milliamperes per square inch.

Three other groups of experiments were conducted with interrupted current using different periods of impulse duration (pulse time). The variation in impulse duration was obtained by using rotating discs with different bronze-Bakelite combinations as already described. In the first group, the disc used was half bronze and half Bakelite. Thus, during each revolution the power was on for one half the time and off for one half the time (1:1 on-off ratio). In the second group of experiments, the disc was three-fourths bronze and one-fourth Bakelite. During each revolution the power would then be on three times as long as it would be off (3:1 on-off ratio). In the third group of experiments one fourth of the interrupting disc was bronze while three fourths was Bakelite. In this case the power was on one fourth of the time and off three fourths of the time during each revolution (1:3 on-off ratio).

Each group of experiments with interrupted current included several series at successively greater amperages. In group I, amperages of 1, 2, 3, 4, and 5 were used. In group II, amperages of 4, 5, 6, 7, and 8 were used. In group III, amperages of 2, 3, and 4 were used. At each amperage within a group, experiments were conducted at several frequencies of interruption. Frequencies used in group I were 5, 10, 15, 20, and 25 interruptions per second. In groups II and III, frequencies of 5, 15, and 25 interruptions per second were used. In each individual experiment, five fish were used and two trials were made with each. The polarity was changed with each trial. In all groups of experiments, successive tests were conducted until a current value was reached that would cause all fish to move to the positive pole and remain there for the full 60 seconds of each time period. If the frequency of current interruption proved to be a factor in causing the desired effect, this would be shown by variation in the times recorded for the different interruptions when both current and voltage remained constant.

## RESULTS

### *Continuous Direct Current*

The results of tests using uninterrupted (continuously flowing) current are shown in Table 1. The fish showed no effects of the current flow at 1, 2, and 3 amperes. At a current value of 4 amperes, the fish swimming near the electrodes, within about 6 inches, would suddenly veer away as though shocked. This effect became noticeable at greater distances from the electrode as the current was increased. At 7 amperes some fish were more strongly shocked in the immediate vicinity of the poles, but reactions were entirely evasive. The fish would swim toward one end of the tank; upon nearing the pole and receiving a shock they would turn and swim rapidly toward the opposite end, where the experience would be repeated.

At a current value of 9 amperes the fish entering the area near the positive pole would show the typical electronarcotic effect, including cramped, slow movements and slowing of opercular action, which resulted in respiratory difficulties. If the fish were at right angles to the lines of force between the electrodes, the body would be bent with the head and tail pointing toward the positive electrode. However, the electrical field was still not powerful enough to hold the fish and they were able to escape this influence, avoid the vicinity of the pole, and swim to an area in the tank where they were affected least.

At current values above 10 amperes practically all fish started swimming toward the positive pole when the center barriers were removed but were repulsed rather than held by the increasing effects as they neared the positive pole. The result was that they remained either in a low-current density area at the bottom of the tank near the pole barriers, or near the center of the tank away from both poles. Their swimming movements were slow and unnatural. The dorsal fin was stiffly elevated.

At a current value of 14 amperes all fish swam toward the positive pole until the barrier was reached. Many tried to force their way through the protective net in their attempts to get nearer the electrode. Soon after reaching the net barrier the electronarcotic effect became evident. The fish could not

TABLE 1

Mean Time (in Seconds for 5 Fish, 2 Trials Each) Spent in the Positive Section of the Tank Using Uninterrupted Direct Current

| AMPERES | MEAN TIME | AMPERES | MEAN TIME |
|---|---|---|---|
| 1 | 33.9 | 8 | 36.9 |
| 2 | 27.9 | 9 | 19.7 |
| 3 | 34.9 | 10 | 38.1 |
| 4 | 26.9 | 11 | 30.2 |
| 5 | 30.9 | 12 | 41.5 |
| 6 | 38.2 | 13 | 46.2 |
| 7 | 32.5 | 14 | 60.0 |

TABLE 2

MEAN TIME (IN SECONDS FOR 5 FISH, 2 TRIALS EACH) SPENT IN THE POSITIVE SECTION OF THE TANK AT VARIOUS FREQUENCIES AND AMPERAGES OF INTERRUPTED CURRENT WITH 1:1 ON-OFF RATIO

| AMPERES | FREQUENCIES | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 |
| 1 | 35.0 | 45.8 | 34.6 | 24.3 | 38.2 |
| 2 | 30.4 | 31.4 | 33.1 | 42.2 | 28.6 |
| 3 | 25.0 | 41.5 | 32.5 | 36.8 | 41.0 |
| 4 | 28.2 | 33.2 | 46.2 | 48.2 | 43.1 |
| 5 | 50.3 | 60.0 | 60.0 | 60.0 | 60.0 |

maintain equilibrium and would sink slowly toward the bottom of the tank, ventral side up. In some, all visible signs of life, including opercular movements, ceased. However, when the power was turned off, all the fish recovered, usually within a few seconds. None died as a result of this series of tests using a constantly flowing current. Of the five fish which were tested at various amperages, one showed in both trials the complete electrotactic and electronarcotic effect at 12 amperes, one at 13 amperes, and all five at 14 amperes. Therefore, 14 amperes was considered the value necessary to cause the fish to come to the positive pole and become immobilized when uninterrupted current at 225 volts was used.

A statistical analysis of the quantitative data of Table 1 was made to supplement the observations reported above. It may be seen that the mean time spent in the positive half of the tank fluctuated between 19.7 and 38.2 seconds in the experiments conducted over a range of amperages from 1 to 11. As indicated by a "t" test, none of these means differed significantly from an expected mean of 30 seconds. At 12 amperes the mean of 41.5 seconds differed significantly from the expected mean of 30 seconds ($t = 2.06$; $P = 0.07$). At 13 amperes the mean of 46.2 seconds was also significant ($t = 4.68$; $P < 0.01$). Thus, with the aholehole, a positive electrotactic effect at a distance of 5.5 feet (the center of the tank) from the electrodes was demonstrated quantitatively at 12 amperes. However, as already pointed out, complete electrotaxis and electronarcosis did not result until a current of 14 amperes was used.

*Interrupted Direct Current*
*1:1 On-Off Ratio*

The tabulated results of experiments with various values of interrupted direct current are shown in Tables 2, 3, and 4. In the first group of experiments the power-off period was equal to the power-on period at all frequencies. Examination of the tables again discloses marked variation in the reaction of individual fish. The desired effect, which immobilized all fish at the positive pole for the full 60 seconds of each test period, was reached at an average current value of 5 amperes (Table 2). This effect occurred at each frequency with the exception of five interruptions per second. An effect comparable to this was not obtained with uninterrupted power until a current of 14 amperes had been reached. This seems to indicate that the interruption in some way of direct current makes it much more effective.

It is obvious that by interrupting the direct current so that the power alternates on and off for equal periods, more efficient use is made of the available power. The question is then raised as to whether the reaction of the fish varies with the duration of the on-or off-period. To obtain information on this

TABLE 3

MEAN TIME (IN SECONDS FOR 5 FISH, 2 TRIALS EACH) SPENT IN THE POSITIVE SECTION OF THE TANK AT VARIOUS FREQUENCIES AND AMPERAGES OF INTERRUPTED CURRENT WITH 3:1 ON-OFF RATIO

| AMPERES | FREQUENCIES | | |
|---|---|---|---|
| | 5 | 15 | 25 |
| 4 | 41.9 | 40.3 | 29.4 |
| 5 | 38.7 | 37.7 | 22.8 |
| 6 | 32.3 | 36.2 | 41.5 |
| 7 | 52.4 | 52.4 | 52.6 |
| 8 | 53.7 | 56.5 | 60.0 |

point, the second and third groups of experiments were conducted, the results of which are given in the following sections.

*Interrupted Direct Current*
*3:1 On-Off Ratio*

The results of tests using a 3:1 on-off ratio are shown in Table 3. From this table it can be seen that the desired effect of holding the fish at the positive pole for the full time of each test was not achieved on all fish until an average current value of 8 amperes was reached, and then only in the tests having 25 interruptions per second. However, an analysis of the results shows that a significant deviation from the expected average of 30 seconds was reached in the tests using 7 amperes; for example, at five interruptions per second $t = 3.18$, $P = 0.01$. The higher amperage required when using the 3:1 on-off ratio resulted in a loss rather than a gain in the efficient use of power. It was then decided to decrease the duration of the on- (pulse) period, using a 1:3 on-off ratio.

*Interrupted Direct Current*
*1:3 On-Off Ratio*

Recorded results of these tests are shown in Table 4. A significant variation from the expected average of 30 seconds was reached at an amperage of 2. At a current value of 3 amperes and a frequency of 25 interruptions per second, all fish tested were immobilized at the positive pole. At a current value of 4 amperes all fish tested at all frequencies showed the maximum effect possible.

The quantitative data in the preceding tables do not, of themselves, indicate the full effect which results when interrupted current and decreased on-period is used. Observation of the reaction of the fish left no doubt that the experiment using the shortest pulse period produced the most violent effects. With uninterrupted current the fish's movements were slowed and inhibited. With interrupted current, as the individual shocks became shorter, the effect it produced became greater. At the shortest pulse period, with an effective current, the fish would often leap out of the water and would frequently skip along the surface, always moving directly toward the positive pole.

*Variation of Response*
*with Frequency of Interruption*

A statistical analysis was made of the relationship between frequency of interruption and time spent at the positive pole. From each group using interrupted current the recorded times at frequencies of 5, 15, and 25 were chosen. These were taken only from the two amperages just below the value that caused maximum effect (60 seconds at the positive pole). The only exception to this was the 8 ampere 3:1 on-off series; these data were added because the maximum effect was shown only in the 25 interruptions per second tests (Table 3). The following were included in the analysis: 1:1 ratio, 3 and 4 amperes; 3:1 ratio, 6, 7, and 8 amperes; 1:3 ratio, 2 and 3 amperes. The effect of different on-off ratios, as well as the effect of the various amperages, was separated by analysis of variance methods from the effect due to frequencies of interruption. The data were transformed logarithmically to conform more closely to normal distribution. The analysis provided the information given in Table 5.

There are significant differences among frequencies ($F = 6.73$; $P = 0.01$). Inspection of the data shows that the higher time averages are associated with the higher frequencies.

TABLE 4

Mean Time (in Seconds for 5 Fish, 2 Trials Each) Spent in the Positive Section of the Tank at Various Frequencies and Amperages of Interrupted Current with 1:3 On-Off Ratio

| AMPERES | FREQUENCIES | | |
|---|---|---|---|
| | 5 | 15 | 25 |
| 2 | 41.3 | 44.5 | 55.9 |
| 3 | 56.3 | 52.0 | 60.0 |
| 4 | 60.0 | 60.0 | 60.0 |

TABLE 5
RESULTS OF STATISTICAL ANALYSIS OF RELATIONSHIP BETWEEN FREQUENCY OF INTERRUPTION AND TIME AT POSITIVE POLE

| SOURCE | DEGREES OF FREEDOM | SUMS OF SQUARES | MEAN SQUARES |
|---|---|---|---|
| Total | 20 | 0.243032 | |
| Blocks | 6 | 0.175656 | 0.029276 |
| Frequencies | 2 | 0.035628 | 0.017814** |
| Discrepance | 12 | 0.031748 | 0.002645 |

Observation of the effect at the various interruptions leads to the conclusion that the lower frequencies are not as effective as those in the middle range. If the pulse duration is short, this is particularly true. At low frequencies there is sufficient time after the fish receives the shock to enable it to turn partially or make other movements to escape the current. As a result, the fish pursues an erratic rather than straight course toward the positive pole. In certain respects, the frequencies near the value of 15 per second have some advantages over higher frequencies used. At higher frequencies the fish receives such a rapid series of shocks that there seems to be insufficient time for it to react between shocks, thus greatly restricting its movements and slowing its progress toward the positive pole. At these higher frequencies, with an effective current, the fish often becomes immobilized at some distance from the pole.

*Relationship between Average and Peak Currents*

One very important fact that enters into the interpretation of the results of the experiments is that all interrupted-current values are average values. These values were adjusted to the desired reading on the ammeter while the interrupting mechanism was in operation. The peak amperage was not indicated by the ammeter during the tests because of the indicator's inertia. The peak amperage is the maximum value that will be reached during the current-on period. For example, when the on-period equaled the off-period and the average current value, as read on the ammeter, was 5 amperes, the peak current reached during each pulse was 10 amperes. This value was read on the ammeter when the interrupter was not in operation.

From Figure 5 it can be seen that the peak current in all cases is similar. It is quite possible that, were the exact current values necessary to achieve the desired effect known, the peak current in all cases might be equal. As it is, the effective average current value in

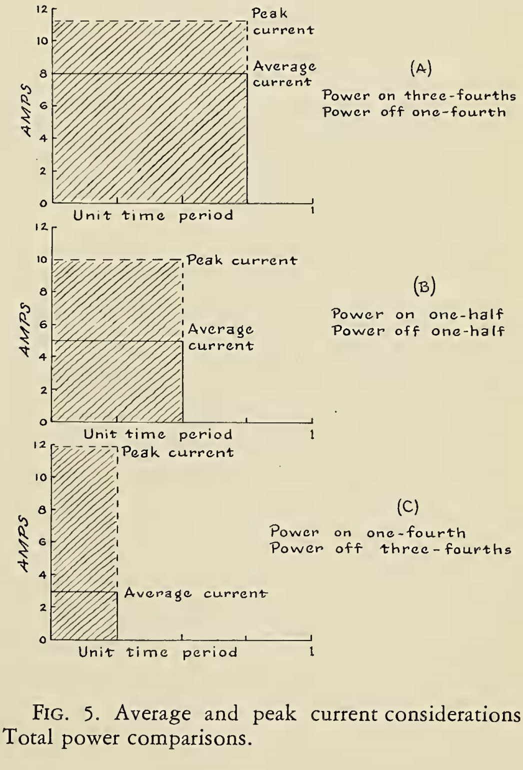


FIG. 5. Average and peak current considerations. Total power comparisons.

graph A (Fig. 5) is known only to be between 7 and 8. If the true average current values were 7.5 amperes for graph A, 5.0 amperes for graph B, and 2.5 amperes for graph C, then the peak current in all cases would be 10.0 amperes.

Decreasing the on- (pulse) period results in a more pronounced electrotactic effect at a lower amperage and also represents a saving in power. It is quite possible that further decreases in the on-time would result in equal electrotactic effects and a still greater saving in power.

The success of electrofishing in the open sea will depend mainly on the ability to make still more efficient use of available power. This is necessary because generators must be able to produce sufficient power, yet be of a size that will permit installation in a fishing boat.

The use of large amounts of electrical power presents a constant element of danger to personnel unless proper precautions are taken. Safety regulations must be strictly observed both in the laboratory and in the field.

## CONCLUSIONS

1. Interrupted direct current is more desirable for electrofishing purposes than uninterrupted current because of the increased electrotactic and electronarcotic effects on the fish.
2. The use of interrupted current in electrofishing represents a considerable saving in power over the use of uninterrupted current.
3. The pulse length of interrupted current can be decreased, at least to some extent, without sacrificing any effectiveness. This results in further power savings.
4. The peak current value reached during a pulse may be the important consideration in causing the response desired in electrofishing.
5. With interrupted direct current, fish can be attracted to the positive pole and immobilized without being killed or injured.

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